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DISEASE DETECTION SURVEY
Air Pollution

Coronado National Forest
Arizona

By
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In September 1971, Robert Loomis, plant pathologist in the Forest Service Insect and Disease Branch, examined trees and associated plants on selected areas of the Coronado National Forest, Arizona. The purpose of the survey was to determine if acute injury had occurred to forest vegetation from SO_2 emitted by the Magma copper smelter, located at San Manuel, Arizona; the Phelps Dodge copper smelter, located at Douglas, Arizona; and the Anaconda copper smelter, located at Cananea, Mexico. No symptoms of acute SO_2 injury to forest vegetation were found on any of the examined areas.

Method.--A detection system, consisting of five sulfation plate stations and seven observation areas, was established during the period June-August 1971. These sulfation plate stations and observation areas are located on the Santa Catalina, Douglas, and Patagonia Ranger Districts of the Coronado National Forest (Figures 1, 3, and 4). Where possible, the sulfation plate stations and observation areas were established in species type and location most susceptible to SO_2 injury. By locating the sulfation plates and observation areas together, we may be able to determine if there is a relationship between sulfation rate and the presence or absence of plant injury. By finding areas most susceptible to SO_2 injury, the detection system is made more sensitive to possible SO_2 injury.

Considerations for establishing observation areas include:

1. Presence of a variety of trees and associated plants growing in the area. One phase in evaluating possible SO_2 injury to plants

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is to determine if similar injury has occurred to a variety of plant species.[1]

2. The observation areas should have adequate soil moisture. Plants growing in areas with adequate soil moisture and high humidity are more susceptible to SO_2 injury than plants growing under arid conditions.[1]

The foliage of trees and associated plants was examined for the interveinal bleaching, interveinal necrosis, and tip burn typical of acute SO_2 injury. In addition, leaf and needle abnormalities from other causes were noted for future reference.

Results.--The following plant species were examined for evidence of acute SO_2 injury:

Forest Trees

Ponderosa pine (Pinus ponderosa)
Pinyon pine (Pinus edulis)
Chihuahua pine (Pinus leiophylla var. chihuahuana)
Apache pine (Pinus latifolia)
Arizona walnut (Juglans major)
Cottonwood (Populus spp.)
Willow (Salix spp.)
Box elder (Acer negundo var. interius)
Wild cherry (Prunus spp.)
Gambel oak (Quercus gambelii)
Arizona white oak (Quercus arizonica)
Arizona alder (Alnus oblongifolia)
Arizona sycamore (Platanus wrightii)
Arizona cypress (Cupressus arizonica)
Douglas-fir (Pseudotsuga menziesii)
Velvet ash (Fraxinus velutina)
Western hackberry (Celtis reticulata)
Desert hackberry (Celtis pallida)
Mesquite (Prosopis juliflora)
Saguaro (Cereus giganteus)
Paloverde (Cercidium spp.)

Forest Plants and Shrubs

Skunkbush (Rhus trilobata)
Sunflower (Helianthus spp.)

1/ Air Pollution Control Assoc. 1970. Recognition of Air Pollution Injury to Vegetation: A Pictorial Atlas. Jacobson, J. S., and A. C. Hill, Editors. Pittsburgh, Pa.

Forest Plants and Shrubs

Wild grape (Vitis spp.)
Poison ivy (Toxicodendron radicans)
Cocklebur (Xanthium saccharatum)
Tree tobacco (Nicotiana glauca)
Ocotillo (Fouquieria splendens)

No symptoms of acute injury were found on trees and plants in any of the areas which were examined. Tree and plant condition was noted as follows:

1. A needle mottle or fleck of unknown cause was noted on second- and third-year needles of ponderosa pines located along the road between Area 2 and Area 5 (Figure 1). This same marking was noted on ponderosa pines in the vicinity of Areas 3 and 9 (Figure 4). The current year's needles did not have this marking.

2. Mortality and symptoms of decline were noted on Chihuahua pine in the vicinity of John Hands and Herb Martyr recreation sites, Douglas Ranger District (Figure 4). This problem is probably a result of at least 2 years of severe drought conditions, and parasitism by the Chihuahua pine dwarf mistletoe (Arceuthobium gillii subsp. gillii).

3. Symptoms which resembled acute SO_2 injury to desert hackberry were noted in early June at the Peppersauce recreation site (Areas 1 and 1A). This area was examined again in September, and no symptoms of acute SO_2 injury were noted on desert hackberry or other trees and plants. At this time, the foliage of several desert hackberry shrubs was severely infected with a fungus-caused disease.

Sulfation plate data for the period August 1971-December 1971 are as follows:

Area 1 - Santa Catalina Ranger District

Month	Days exposed	* Sulfation rate (Micrograms $SO_3/cm^2/day$)
Aug.	29	** <Detectable minimum
Sep.	23	<Detectable minimum
Oct.	34	1.2
Nov.	29	2.8
Dec.	32	3.4

* Corning Laboratories, Inc., Cedar Falls, Iowa, supplies and analyzes all sulfation plates.

** Detectable minimum for 30-day period (micrograms $SO_3/cm^2/day$)
Aug. 1971-Sep. 1971 - 1.0
Oct. 1971-Dec. 1971 - 0.8

Area 1A - Santa Catalina Ranger District

Month	Days exposed	* Sulfation rate (Micrograms $SO_3/cm^2/day$)
Aug.	29	** <Detectable minimum
Sep.	23	<Detectable minimum
Oct.	34	1.7
Nov.	29	2.8
Dec.	32	5.2

Area 2 - Santa Catalina Ranger District

Aug.	29	<Detectable minimum
Sep.	23	<Detectable minimum
Oct.	34	1.2
Nov.	29	<Detectable minimum
Dec.	32	<Detectable minimum

Area 5 - Santa Catalina Ranger District

Aug.	32	<Detectable minimum
Sep.	27	<Detectable minimum
Oct.	29	1.4
Nov.	27	<Detectable minimum
Dec.	35	<Detectable minimum

Area 3 - Douglas Ranger District

Aug.	36	1.3
Sep.	26	<Detectable minimum
Oct.	30	<Detectable minimum
Nov.	33	<Detectable minimum
Dec.	42	<Detectable minimum

Area 4 - Douglas Ranger District

Aug.	36	<Detectable minimum
Sep.	26	<Detectable minimum
Oct.	30	<Detectable minimum
Nov.	33	<Detectable minimum
Dec.	42	<Detectable minimum

* Corning Laboratories, Inc., Cedar Falls, Iowa, supplies and analyzes all sulfation plates.

** Detectable minimum for 30-day period (micrograms $SO_3/cm^2/day$)
Aug. 1971-Sep. 1971 - 1.0
Oct. 1971-Dec. 1971 - 0.8

Discussion.--Diagnosis of air pollution injury to vegetation is complicated by environmental, insect, and other disease factors. These factors can cause leaf and plant symptoms which appear similar to air pollution injury. In addition, the occurrence or severity of air pollution-caused plant injury is determined not only by the pollutant concentrations and duration of exposure, but by many environmental factors which can affect individual plant sensitivity. These factors include light, moisture, temperature, and nutrient relations.2/

To date, the only places we have found acute SO_2 injury to Southwestern forest vegetation have been within 4 miles of the sources emitting SO_2.3/ 4/ Therefore, the lack of acute injury symptoms might be expected on the Douglas and Patagonia Ranger Districts (Figures 3 and 4) because susceptible forest vegetation is more than 25 miles from the sources of SO_2.

Forest vegetation in Areas 1 and 2 on the Santa Catalina Ranger District (Figure 1) is 7 miles from the San Manuel smelter. The foliage symptoms on desert hackberry, which were noted in June, resembled the interveinal bleaching symptoms typical of acute SO_2 injury. We believe that these symptoms were not caused by SO_2 air pollution because similar symptoms were not noted on other trees or plants in either our June or September examinations.

Sulfation rates for the months of August-December in Areas 1 and 2 were low. This would indicate either that low levels of SO_2 or other sulfur compounds are reaching these areas, or that high levels of SO_2 or other sulfur compounds are only infrequently reaching these areas. Schell et al. (1970) reported that "Pollution channels exist thru which SO_2 diffuses. The most prominent is the Gila River Valley between Hayden and Florence. Others are the San Pedro Valley between San Manuel and Redington, and the Gila River Valley northeast of Hayden."5/ The San Pedro Valley drainage is located to the east of Areas 1 and 2, and may account for the low sulfation rates recorded in these areas.

2/ Treshow, M. 1970. Environment and Plant Response. McGraw-Hill Book Co., N. Y. 422 p.

3/ Loomis, R. C. 1971. Disease Detection Survey, Air Pollution, Apache National Forest, Arizona. Office Report, USDA, Forest Service, Southwestern Region. 9 p.

4/ Loomis, R. C. 1971. Disease Detection Survey, Air Pollution, Tonto National Forest, Arizona; Sierra Ancha Experimental Forest, Arizona. Office Report, USDA, Forest Service, Southwestern Region. 15 p.

5/ Schell, N. E., C. A. Lindstrom, and J. L. Guyton. 1970. Sulfation Rates in Copper Smelter Areas of Arizona in 1969-1970. Ariz. Dept. of Health, Environmental Health Services, Div. of Air Pollution Control. Unpublished Project Report.

In addition to looking at vegetation on the observation areas, trees and plants were examined at various points along the road between observation areas. Symptoms of acute SO_2 injury were noted on sunflower foliage located between Oracle and Area 1 (Figure 1). Vegetation was also examined along Copper Creek near the Galiuro Mountains (Figure 2). Trees and plants growing in this area are typical desert vegetation, which, due to the arid conditions, is resistant to SO_2 injury. No symptoms of acute SO_2 injury were found.

The needle mottle or fleck on ponderosa pine, noted near Areas 2, 3, 5, and 9, has been found in New Mexico and Arizona for many years. This needle marking can be found in areas far from any known sources of air pollution, as well as areas close to industrial activity. We are now attempting to determine if the appearance of this marking is related to a particular time of year. In addition, we are working with Forest Service research plant pathologists, and members of the University of Arizona Department of Plant Pathology, in trying to determine the cause of this needle marking.

Sulfation plates are being used to determine if SO_2 and other sulfur compounds are reaching the vegetative observation areas.6/ The sulfation plates are exposed for approximately 30 days, during which time sulfur compounds react with the lead dioxide in the plate. The product of these reactants is then measured and expressed as micrograms $SO_3/cm^2/day$.7/ This is commonly called the sulfation rate. To date, no relationship has been noted between sulfation rate and the presence of plant injury. Comparisons have not been possible because most of the acute plant injury we have found has not been in the vicinity of our sulfation plate stations. Eventually, it may be possible to develop an area plant hazard rating system based on monthly average sulfation rates and relative susceptibility of native forest species.

In order to get some idea of sulfation plate reliability, duplicate plates were exposed in Area 1 (Areas 1 and 1A) and in five other locations in Arizona and New Mexico. The sulfation rates of several individual plate-pairs varied considerably; however, when all plate-pairs are considered, there is a highly significant correlation between the sulfation rates on each of the plate-pairs ($R = 0.859$ with 26 degrees of freedom). There is no significant difference between the average of the means of each set of plate-pairs ($T = 1.03$ with 26 degrees of freedom).

6/ Tucson Advisory Committee on Air Pollution. 1971. Air Pollution in Tucson: A Report to the Mayor and Council of the City of Tucson. Edited by R. Caldwell. 141 p.
7/ Huey, N. A. 1968. The Lead Dioxide Estimation of Sulfur Dioxide Pollution. J. Air Poll. Control Assoc. 18: 9.

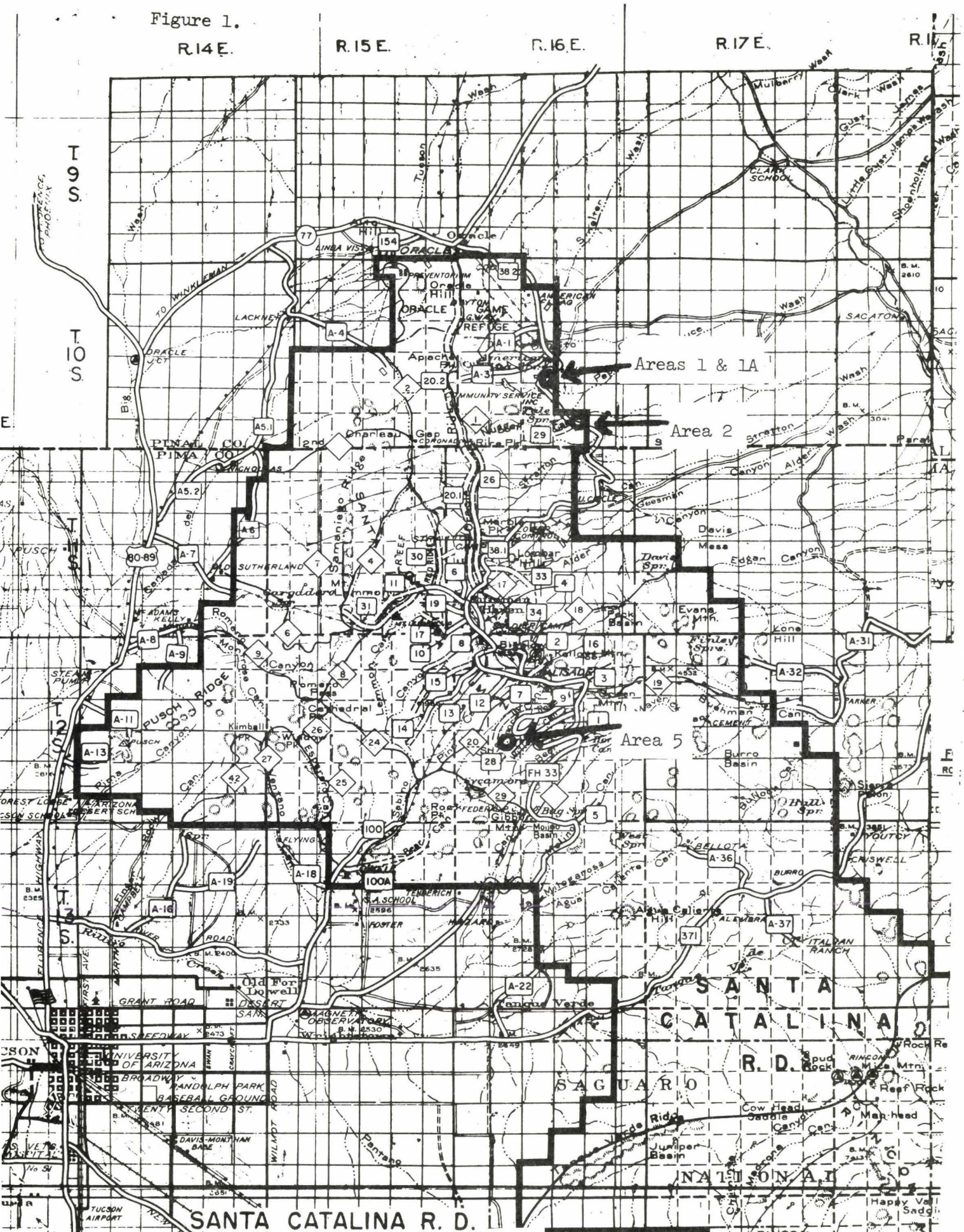
A map is attached which shows the areas included in the 1971 air pollution detection survey.

Recommendations.--

1. Examine selected areas of the Coronado National Forest, in the late summer of 1972, for evidence of acute or chronic injury caused by SO_2.

2. Continue the present sulfation plate network at least until November 1972. More information is needed concerning sulfation rate and the presence or absence of plant injury.

Figure 1.


R.14 E.
R.15 E.
R.16 E.
R.17 E.
T. 9 S.
T. 10 S.
T. 12 S.
T. 13 S.
Areas 1 & 1A
Area 2
Area 5
SANTA CATALINA R.D.
SAGUARO NATIONAL
ORACLE
ORACLE JCT.
SACATON
CLARK SCHOOL
PINAL CO.
PIMA CO.
SUTHERLAND
PUSCH RIDGE
SANTA CATALINA MTS.
Oracle Hill
Apache Pk.
Charleston Gap
Romero Pools
Cathedral
Kimball Pk.
Wilson Pk.
Redington Pass
Rincon Pk.
Tanque Verde
Old Fort Lowell
Tucson Airport
University of Arizona
Broadway
Randolph Park
Baseball Ground
Twenty Second St.
Davis-Monthan Base
Wilmot Road
Alvernon Way
Campbell Ave.
Swan
Craycroft
Speedway
Grant Road
Desert
Magnet Observatory
Foster
Tenerich
Hagard
Flying
Ruthrauff Road
Florence Highway
Old Spanish Trail
Arizona Desert Sch.
Forest Lodge
Tucson Sch.
Pusch Ridge
Romero Canyon
Sabino Canyon
Bear Canyon
Pima Canyon
Finger Rock Canyon
Cañada del Oro
Big Wash
Tucson Wash
Pantano Wash
Rillito Creek
Agua Caliente
Agua Caliente Hill
Alamo Canyon
Italian Ranch
Bellota
Burro Basin
Burro Mtns.
Mt. Lemmon
Mt. Kimball
Mt. Wrightson
Mt. Fagan
Mt. Bigelow
Mt. Kelly
Mt. Adams
Mt. Gilbert
Mt. Monroe
Mt. Evans
Mt. Kane
Mt. Hirst
Mt. Hutton
Mt. Lemmon Fire Tower
Mt. Lemmon Ski Run
Mt. Lemmon Ski Valley
Mt. Lemmon Ski Basin
Mt. Lemmon Ski Tow
Mt. Lemmon Ski Lodge
Mt. Lemmon Ski Chalet
Mt. Lemmon Ski Cabin
Mt. Lemmon Ski Hut
Mt. Lemmon Ski Shelter
Mt. Lemmon Ski Warming Hut
Mt. Lemmon Ski Warming Shelter
Mt. Lemmon Ski Warming Cabin
Mt. Lemmon Ski Warming Lodge
Mt. Lemmon Ski Warming Chalet
Mt. Lemmon Ski Warming Tow
Mt. Lemmon Ski Warming Valley
Mt. Lemmon Ski Warming Basin
Mt. Lemmon Ski Warming Run
Mt. Lemmon Ski Warming Hill
Mt. Lemmon Ski Warming Mtn.
Mt. Lemmon Ski Warming Pk.
Mt. Lemmon Ski Warming Ridge
Mt. Lemmon Ski Warming Canyon
Mt. Lemmon Ski Warming Wash
Mt. Lemmon Ski Warming Creek
Mt. Lemmon Ski Warming Spr.
Mt. Lemmon Ski Warming Tank
Mt. Lemmon Ski Warming Well
Mt. Lemmon Ski Warming Mine
Mt. Lemmon Ski Warming Camp
Mt. Lemmon Ski Warming Trail
Mt. Lemmon Ski Warming Road
Mt. Lemmon Ski Warming Highway
Mt. Lemmon Ski Warming Bridge
Mt. Lemmon Ski Warming Tunnel
Mt. Lemmon Ski Warming Pass
Mt. Lemmon Ski Warming Gap
Mt. Lemmon Ski Warming Saddle
Mt. Lemmon Ski Warming Ridge
Mt. Lemmon Ski Warming Peak

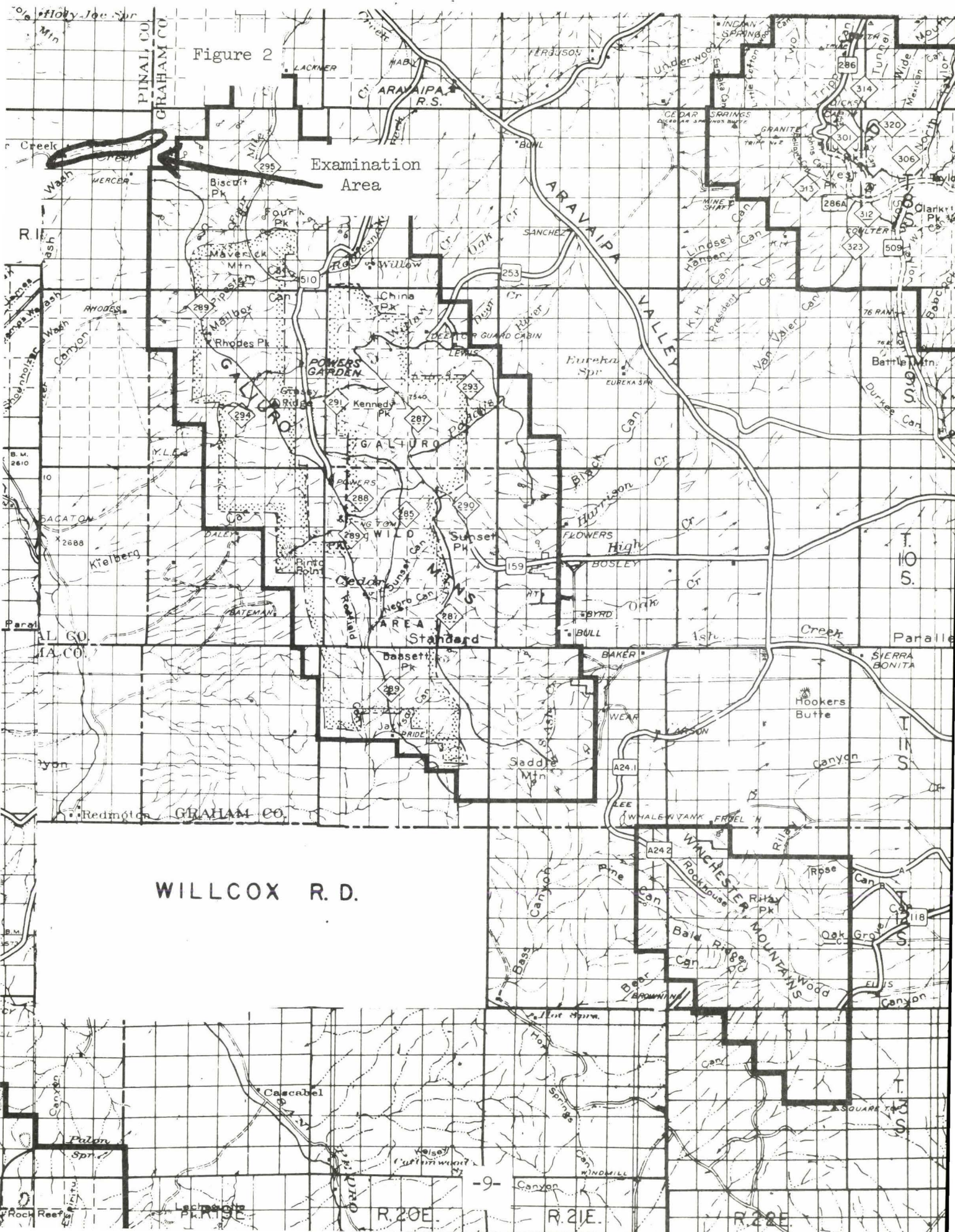


Figure 2
Examination Area
PINAL CO.
GRAHAM CO.
ARAVAIPA R.S.
ARAVAIPA VALLEY
GALIURO
GALIURO MTNS
POWERS GARDEN
AREA
WILLCOX R. D.
WINCHESTER MOUNTAINS
Redington
Cascabel
Saddle Mtn
Maverick Mtn
Rhodes Pk
Kennedy Pk
Babbett Pk
Riley Pk
Clarkr Pk
Battle Mtn.
Hookers Butte
Sierra Bonita
Eureka Spr
Indian Springs
Cedar Springs
Granite Tank
Coulter
Flowers
Bosley
Byrd
Bull
Baker
Wear
Larson
Lee
Whalen Tank
Fuel
Standard
Bateman
Gaton
Kielberg
Rock Reef
Palm Spr.
Lechuguilla Pk.
R.19E.
R.20E.
R.21E.
R.22E.
T. 10 S.
T. 11 S.
T. 12 S.
T. 13 S.
R. 11 E.

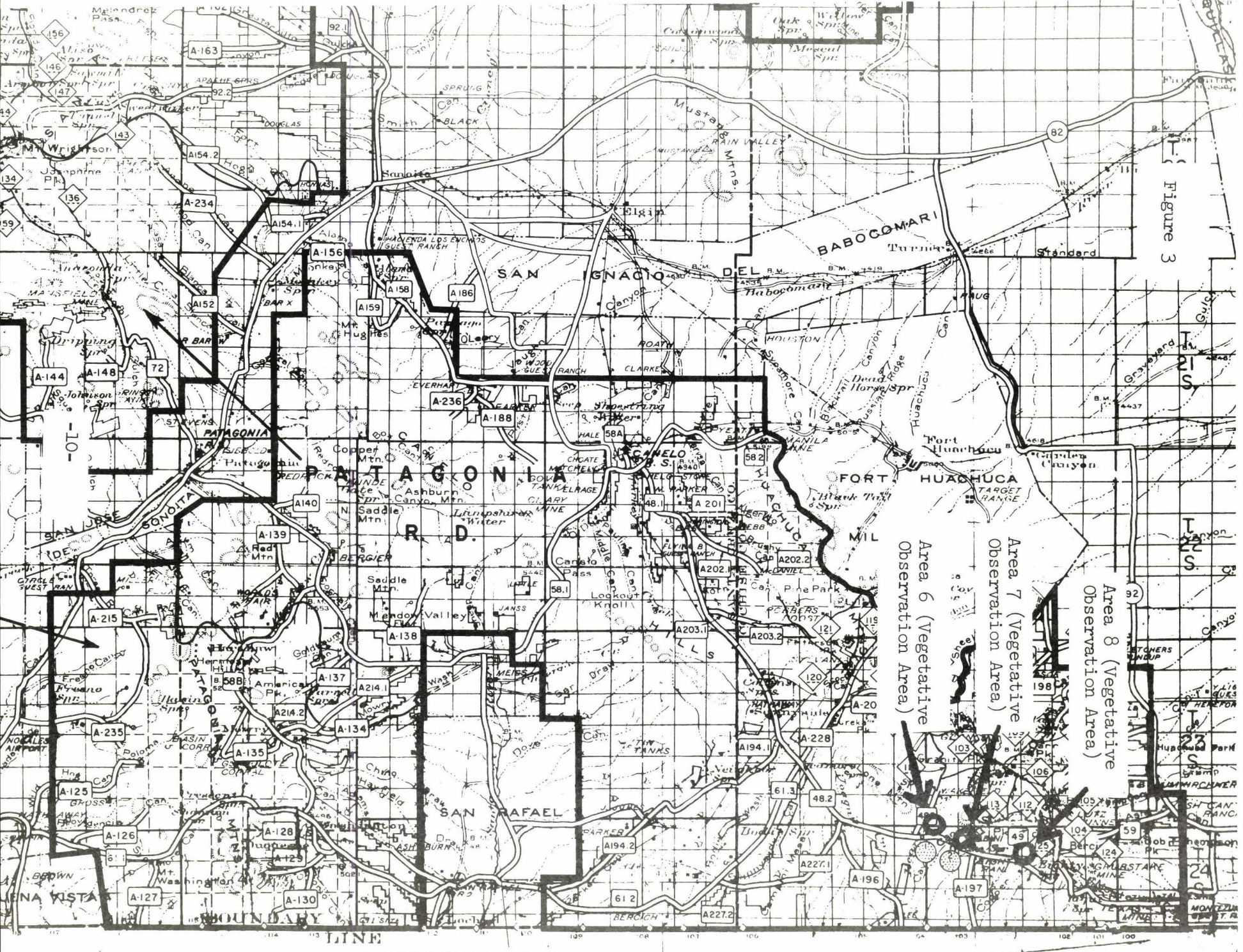
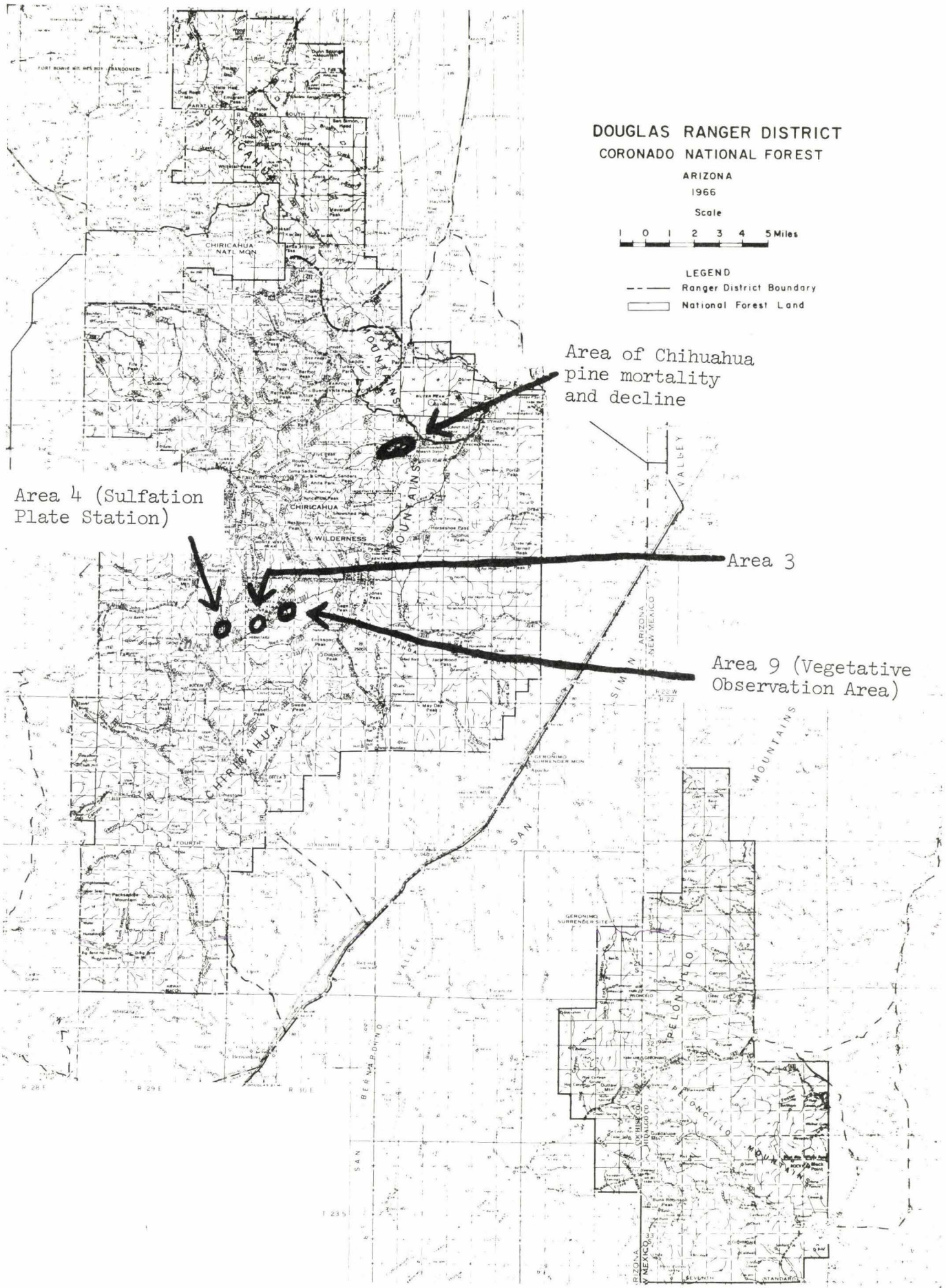


Figure 3
Area 6 (Vegetative Observation Area.)
Area 7 (Vegetative Observation Area.)
Area 8 (Vegetative Observation Area.)
PATAGONIA
SAN IGNACIO DEL BABOCOMARI
FORT HUACHUCA
SAN RAFAEL
BOUNDARY LINE
R 15 E.
R 16 E.
PATAGONIA R. D.
R 18 E.
R 19 E.
R 20 E.
R 21 E.
T 21 S.
T 22 S.
T 23 S.
T 24 S.

Figure 4


DOUGLAS RANGER DISTRICT
CORONADO NATIONAL FOREST
ARIZONA
1966
Scale
1 0 1 2 3 4 5 Miles
LEGEND
Ranger District Boundary
National Forest Land
Area of Chihuahua pine mortality and decline
Area 4 (Sulfation Plate Station)
Area 3
Area 9 (Vegetative Observation Area)
CHIRICAHUA NATL MON
CHIRICAHUA WILDERNESS
CHIRICAHUA MOUNTAINS
SAN SIMON VALLEY
ARIZONA
NEW MEXICO
PELONCILLO MOUNTAINS
SAN BERNARDINO VALLEY
GERONIMO SURRENDER SITE
FORT BOWIE NHS (RES BDY ABANDONED)

AIR POLLUTION DETECTION SURVEY - 1971
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